



Education: Inspiring Students as Only NASA Can

Introduction

Helen Lane
Kamlesh Lulla

The Challenger Center

June Scobee Rodgers

The Michael P. Anderson Engineering Outreach Project

Marilyn Lewis

Long-distance Calls from Space

Cynthia McArthur

Project Starshine

Gilbert Moore

Earth Knowledge Acquired by Middle School Students

Sally Ride
Kamlesh Lulla

Toys in Space

Carolyn Sumners
Helen Lane
Kamlesh Lulla

Flight Experiments

Dan Caron
John Vellinger

Spaceflight Science and the Classroom

Jeffery Cross

Teachers Learn About Human Spaceflight

Susan White

College Education

Undergraduate Engineering Education

Aaron Cohen

Graduate Student Science Education

Iwan Alexander

NASA's commitment to education is played out with the Space Shuttle, but why?

“And to this end nothing inspires young would-be scientists and engineers like space and dinosaurs—and we are noticeably short of the latter.”

— Norman Augustine, former president and CEO of Lockheed Martin Corporation

Every Space Shuttle mission was an education mission as astronauts always took the time, while in orbit, to engage students in some kind of education activity. In fact, the shuttle served as a classroom in orbit on many missions.

Of the more than 130 flights, 59 included planned student activities. Students, usually as part of a classroom, participated in downlinks through ham radio (early in the program) to video links, and interacted with flight crews. Students asked lots of questions about living and working in space, and also about sleep and food, astronomy, Earth observations, planetary science, and beyond. Some insightful questions included: Do stars sparkle in space? Why do you exercise in space?

Through student involvement programs such as Get Away Specials, housed in the shuttle payload bay, individual students and classes proposed research. If selected, their research flew on the shuttle as a payload. Students also used the astronaut handheld and digital-camera photos for various research projects such as geology, weather, and environmental sciences in a program called KidSat (later renamed Earth Knowledge Acquired by Middle School Students [EarthKAM]). Teacher materials supported classroom EarthKAM projects. Concepts of physics were brought to life during Toys in Space payload flights. Playing with various common toys demonstrated basic physics concepts, and teacher materials for classroom activities were provided along with the video from spaceflight. Not all education projects were this specific, however. Starshine—a satellite partially built by middle school students and launched from the shuttle payload—provided data for scientific analysis completed by students from all over the world. In fact, most of the scientific missions contained student components. Students usually learned about research from the principal investigators, and some of the classrooms had parallel ground-based experiments. Teacher workshops provided instruction on how to use the space program for classrooms.



The Space Shuttle became a true focus for education when President Ronald Reagan announced the Teacher in Space Program in 1984. Of course, the pinnacle of NASA's educational involvement was the selection of Astronaut Christa McAuliffe, first teacher in space. Although her flight was cut short (Challenger accident in 1986), she inspired the nation's educators. Created as a legacy of the Challenger crew by June Scobee, Challenger Centers focus on scientific and engineering hands-on education to continue NASA's dedication to education. Barbara Morgan, the backup to Christa, flew 11 years later as the educator astronaut on Space Transportation System (STS)-118 (2007), and this program continues. From the Columbia accident (2003), the education legacy continued with the establishment of the Michael P. Anderson Engineering Outreach Project in Huntsville, Alabama, to promote education of minority students through hands-on science and engineering.

Educational activities were, indeed, an integral part of the Space Shuttle Program.



Sivaker Strithar, fifth-grade student at the Harry Eichler School, New York City Public School 56Q, compares the growth of seeds flown on the Space Shuttle with earthbound control seeds. NASA flew 10 million basil seeds on STS-118 (2007) to mark the flight of the first educator and mission specialist, Barbara Morgan. The seeds were distributed to students and educators throughout the country.

Donald Thomas, PhD
Astronaut on STS-65 (1994),
STS-70 (1995),
STS-83 (1997), and
STS-94 (1997).



*"The Space Shuttle
has without a
doubt demonstrated
remarkable engineering
and scientific*

achievement, but I believe an even more impressive accomplishment and enduring legacy will be its achievements in the field of education. The Space Shuttle was not just another space program that students were able to watch 'from the sidelines.' It was a program in which they could participate first-hand, speaking directly with the astronauts and performing their own original research in space with experiments like SEEDS, SAREX**, and many more. For the first time we made access to space available to the classroom, and many teachers and students from across the country and around the world were able to participate. Since its first flight in 1981, the Space Shuttle, its crews, and the NASA team have inspired a whole generation of students. By exciting them and motivating them to work hard in the STEM (Science, Technology, Engineering, and Mathematics) disciplines, the Space Shuttle Program has helped prepare this next generation of scientists and engineers to take over the torch of exploration as we move from the Space Shuttle to Orion*** and resume our exploration of the moon, Mars, and beyond."*

**SEEDS—Space Exposed Experiment Developed for Students*

***SAREX—Space Shuttle Amateur Radio Experiment*

****Crew Exploration Vehicle named Orion*



Kindergarten Through 12th Grade Education Programs

The Challenger Center

The Challenger Center for Space Science Education, created by the families of the Space Shuttle Challenger astronauts, is an outstanding example of how a tragic event can be transformed into a positive force for educational achievement across the nation.



Christa McAuliffe, payload specialist and first Teacher in Space, trains on shuttle treadmill for Challenger flight STS-51L. The Challenger accident occurred on January 28, 1986.

Education became the primary focus of the Challenger STS-51L (1986) mission as teacher Christa McAuliffe was to use the shuttle as a “classroom in space” to deliver lessons to children around the world. It was to be the ultimate field trip of discovery and exploration; however, the Space Shuttle Challenger and her crew perished shortly after liftoff, and the vision for education and exploration was not realized.

The goal of the Challenger Center and its international network of Challenger

Learning Centers is to carry on the mission of Space Shuttle Challenger and continue “Inspiring, Exploring, Learning” for the next generation of space pioneers and teachers.

Since its inception in 1986, the Challenger Center has reached more than 8 million students and teachers through its 53 centers scattered across the globe. Using simulation in a Mission Control Center and space station environment, expert teachers foster learning in science, mathematics, engineering, and technology. In fact, each year, more than 500,000 students and 25,000 educators experience hands-on learning in those disciplines. The Challenger Center simulators provide cooperative learning, problem solving, decision making, and teamwork—all key ingredients of any successful mission. This experiential learning is structured to support the National Science Education Standards as well as national standards in mathematics, geography, technology, and language arts. Using “Mission to Planet Earth” as one of the themes, the center also inculcates, in young minds an awareness of global environmental issues.

The centers offer a wholesome, integrated, and engaging learning environment. It is truly an authentic science- and mathematics-based learning approach that grabs students’ attention, engages them to develop problem-solving skills, and provides satisfaction of accomplishing a tough mission during a team effort that takes them to the moon, Mars, or even Jupiter.

Educators wholeheartedly support this learning environment. For example, the State Board of Education in Virginia considered the Challenger Center model to be highly effective, and the US Department of Education cited the center as significantly impacting science literacy in the country.



Students at a Challenger Center learning about shuttle science by working in a glove box.

A former governor of Kentucky requested three Challenger Learning Centers for his state to improve the science literacy of Kentucky’s youth population. Police officials in Canada created a Challenger Center as a gift to the youth for nontraditional outreach uses. Other youth groups, such as the Girl Scout and Boy Scout organizations, also participated.

Tomorrow’s aerospace and scientific workforce and the destiny of our nation’s space exploration leadership are being shaped in Challenger Learning Centers across our nation. This is a powerful educational bridge that the Space Shuttle helped build for “teaching and touching the future.”

The Michael P. Anderson Engineering Outreach Project

The Michael P. Anderson Engineering Outreach Project is part of the educational legacy of the Space Shuttle. Named for Columbia Astronaut Michael Anderson (who lost his life in the accident), the project seeks to engage underserved high school students in engineering design challenges in aerospace, civil, mechanical, and electrical engineering so these students become aware of engineering career options. Participating students learn about the life and accomplishments of Anderson, and they see him as a role model.



Astronaut Michael Anderson (Lieutenant Colonel, US Air Force) flew on STS-89 (1998) and then on the ill-fated Columbia (STS-107 [2003]).

The objectives are to inspire students to prepare for college by taking more advanced mathematics courses along with improved problem-solving skills, and by learning more about the field of engineering. Parents are involved in helping plan their child's academic career in science, mathematics, or engineering.

Students participate in a 3-week training program each summer. Alabama A&M School of Engineering faculty and NASA employees serve as students' leaders and mentors. At the end, the students present their engineering and mathematics projects. The curriculum and management design are disseminated from these activities to other minority-serving institutions.



Michael P. Anderson Project students Alecea Kendall, a tenth-grade New Century Technology student, and Hilton Crenshaw, a tenth-grade Lee High student, work as a team to assemble their LEGO NXT Mindstorm robot.

Long-distance Calls from Space

Students and teachers have friends in high places, and they often chat with them during shuttle missions. In November 1983, Astronaut Owen Garriott carried a handheld ham radio aboard Space Shuttle Columbia. The ham radio contacts evolved into the Space Shuttle Amateur Radio Experiment, which provided students with the opportunity to talk with shuttle astronauts while the astronauts orbited the Earth. Ham radio contacts moved from shuttle to the International Space Station, and this activity has

transitioned to amateur radio on board the International Space Station. In addition to ham radio contacts, students and teachers participated in live in-flight education downlinks that included live video of the astronauts on orbit. The 20-minute downlinks provided a unique learning opportunity for students to exchange ideas with astronauts and watch demonstrations in a microgravity environment. Ham radio contacts and in-flight education downlinks allowed more than 6 million students to experience a personal connection with space exploration.

Astronauts Speak to Students Through Direct Downlink



The STS-118 (2007) crew answering a student's question.



Elementary school student asking the crew a question.



Student watching the downlink for STS-118.

Students participated in in-flight education downlinks that included live video of the astronauts on orbit. Students asked questions and exchanged ideas with astronauts.



Project Starshine

Project Starshine engaged approximately 120,000 students in more than 4,000 schools in 43 countries.

NASA deployed reflective spherical student satellites from two separate shuttle missions—STS-96 (1999) and STS-108 (2001). NASA had flown a third satellite on an expendable launch vehicle mission, and a fourth satellite was manifested on a shuttle mission but later cancelled following the Columbia accident (STS-107 [2003]). A coalition of volunteer organizations and individuals in the United States and Canada built the satellites. Each satellite was covered by approximately 1,000 small front-surface aluminum mirrors that were machined by technology students in Utah and polished by tens of thousands of students in schools and other participating organizations around the world. During the orbital lifetime of the satellites, faint sunlight flashes from their student-polished mirrors were visible to the naked eye during certain morning and evening twilight periods. The student observers



Students in the Young Astronauts/Astronomy Club at Weber Middle School in Port Washington, New York, proudly display a set of mirrors destined for Starshine.

measured the satellites' right ascension and declination by reference to known stars, and they recorded the precise timing of their observations through the use of stopwatches synchronized with Internet time signals. They used global positioning satellite receivers or US Geological Survey 7.5-minute quadrangle maps, or their equivalents in other countries, to measure the latitude, longitude, and altitude of their observing sites. They posted their observations and station locations on the Starshine Web site.



Launching Starshine satellite from Endeavour's payload bay during STS-108 (2001).

As an example of Project Starshine, children in the Young Astronauts/Astronomy Club at Weber Middle School in Port Washington, New York, contributed to the project.

"The club members arrived at school at 7:30 a.m. every day to make sure the project would be completed on time. They worked diligently and followed instructions to the letter," said their science teacher, Cheryl Dodes.

Earth Knowledge Acquired by Middle School Students

How does one inspire school students to pursue science and engineering? Imagine creating an opportunity for students to participate in space operations during real Space Shuttle flights.

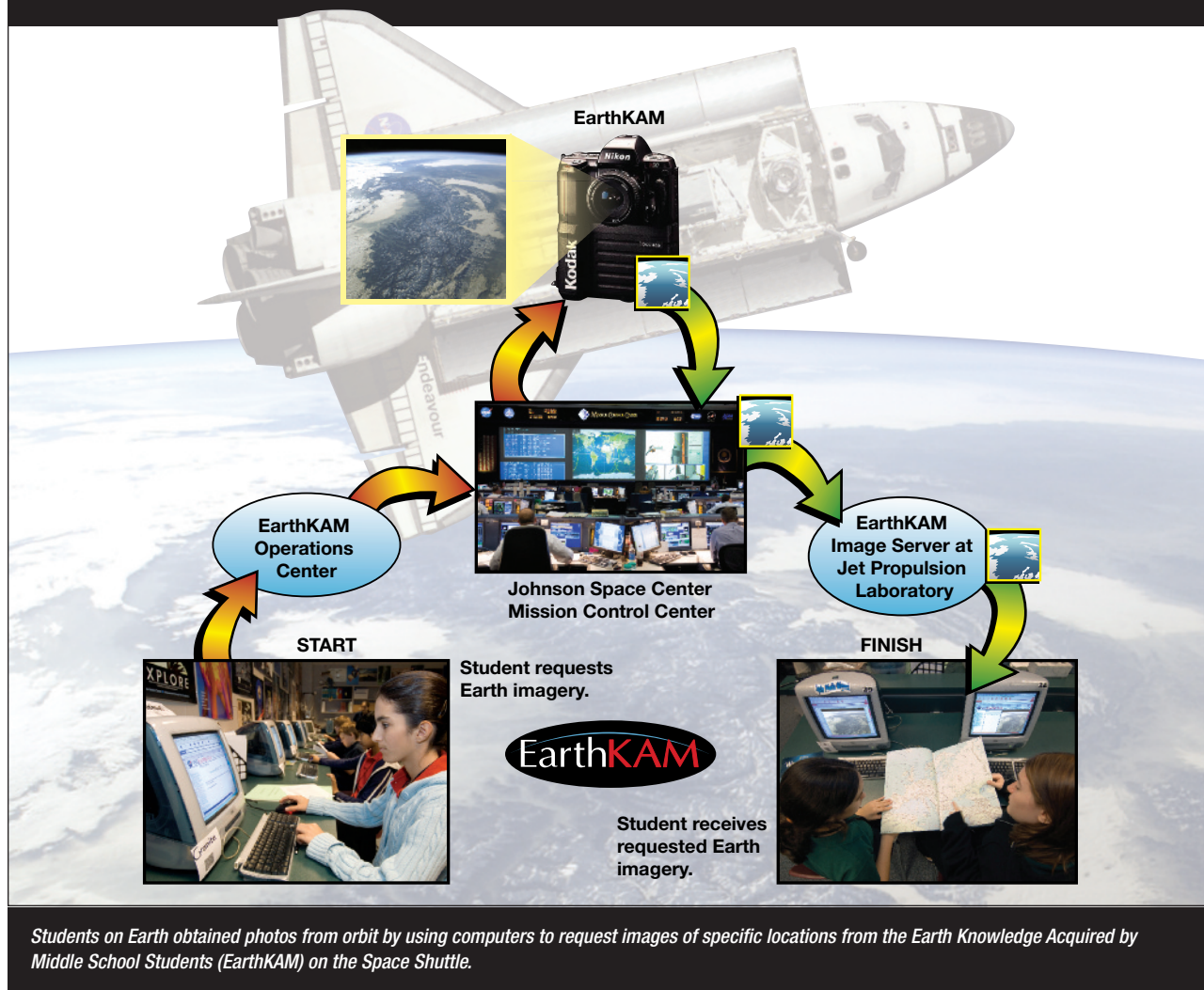
The brainchild of Dr. Sally Ride—first American woman in space—the **Earth Knowledge Acquired by Middle School Students (EarthKAM)** education program, sponsored by NASA, gives students "hands-on" experience in space operations. During the Space Shuttle Program, NASA's EarthKAM was the next best thing to being on board for junior scientists.

The idea is as simple as it is elegant: by installing a NASA camera on board a spacecraft, middle school students across the United States and abroad had front-row seats on a space mission. They used images to study Earth science and other science disciplines by examining river deltas, deforestation, and agriculture. The hardware consisted of an electronic still camera and a laptop that was set up by an astronaut and then operated remotely from the ground with imaging requests coming directly from the students.

While this hands-on, science-immersive learning was cool for kids, the high-tech appeal was based on proper science



Students as Virtual Astronauts



methods. Students prepared a solid research proposal outlining the topic they wanted to study. The program was similar to a time-share facility. Schools were to take a certain number of photographs. During the Space Shuttle Program, students set up a 24-hour classroom Mission Control operation to track the shuttle's orbit. By calculating latitude and longitude, they followed the shuttle's route and monitored weather conditions. After choosing photo targets, students relayed

those instructions over the Internet to University of California at San Diego operations unit. Undergraduate volunteers wrote the code that instructed the camera when to acquire imagery. The students received their photo images back through the Web site and began analyzing their data.

Since its first launch in 1996, EarthKAM flew on six shuttle missions and now continues operations on the International Space Station. To date, more than 73,000 students from 1,200 schools in

17 countries have participated in the program. This exciting adventure of Earth exploration from space is a great hit at schools all over the globe. While youngsters can learn latitude, longitude, and geography from a textbook, when their lesson comes first-hand from the Space Shuttle, they really pay attention. "In 20 years of teaching," says Sierra Vista Middle School (California) teacher Mark Sontag, "EarthKAM is by far the most valuable experience I've ever done with kids."



Toys in Space: Innovative Ways to Teach the Mechanics of Motion in Microgravity

Toys are the technology of childhood. They are tools designed to be engaging and fun, yet their behaviors on Earth and on orbit can illustrate science, engineering, and technology concepts for children of all ages. The STS-51D (1985) crew carried the first 11 toys into orbit. The STS-54 mission (1993) returned with some of those toys and added 29 more. The STS-77 (1996) mission crew returned with 10 of the STS-54 toys that had not been tested in space. For all these missions, crews also carried along the questions of curious children, teachers, and parents who had suggested toy experiments and predicted possible results. A few dozen toys and a few hours of the crew members' free time brought the experience of free fall and an understanding of gravity's pull to students of all ages.

Toys included acrobats (showing the positive and negative roles of gravity in earthbound gymnastics)—toy planes, helicopters, cars, and submarines (action-reaction in action), spinning tops, yo-yos, and boomerangs (all conserving angular momentum), magnetic marbles and coiled-spring jumpers (conserving energy), and the complex interplay of friction and Newton's Laws in sports, from basketball and soccer to horseshoes, darts, jacks, Lacrosse, and jump rope.

Toys are familiar, friendly, and fun—three adjectives rarely associated with physics lessons. Toys are also subject to gravity's downward pull, which often stops their most interesting behaviors. Crew members volunteered to perform toy experiments on orbit where gravity's tug would no longer affect toy activities. Toy behaviors on Earth and in space

could then be compared to show how gravity shapes the motions of toys and of all other moving objects held to the Earth's surface.

The toys were housed at the Houston Museum of Natural Science after flights. A paper airplane toy used during the flight of US Senator Jake Garn (shuttle payload specialist) was displayed at the Smithsonian Air and Space Museum in Washington DC. McGraw-Hill published two books for teachers on using the Toys in Space Program in the classroom. NASA created a DVD on the International Toys in Space Program with the other Toys in Space videos included. The DVD also provided curriculum guides for all of the toys that traveled into space.

The Toys in Space Program integrated science, engineering, and technology.

Toys in Space on Discovery, STS-51D (1985)



Astronauts Jeffrey Hoffman and Rhea Seddon worked with a coiled spring. The spring demonstrated wave action in microgravity.



Astronaut Donald Williams plays with a paddleball. He could stick the ball at any angle because very little gravity pulled the ball.

The National Science Education Standards recognized that scientists and engineers often work in teams on a project. With this program, students were technicians and engineers as they constructed and evaluated toys. They became scientists as they experimented with toys and predicted toy behaviors in space. Finally, they returned to an engineering perspective as they thought about modifying toys to work better in space or about designing new toys for space. Designing for space taught students that technical designs have constraints (such as the shuttle's packing requirements) and that perfect solutions are often not realistic. Space toys, like space tools, had to work in a new and unfamiliar environment. Ultimately, however, Toys in Space was about discovering how things work on Spaceship Earth.



Flight Experiments: Students Fly Research Projects in Payload Bay

The Space Shuttle provided the perfect vehicle for students and teachers to fly experiments in microgravity. Students, from elementary to college, participated in the Self-Contained Payload Program—popularly named Get Away Specials—and the Space Experiment Modules Program. These students experienced the wonders of space.

Get Away Specials

Get Away Specials were well suited to colleges and universities that wished for their students to work through the engineering process to design and build the hardware necessary to meet criteria and safety standards required to fly aboard the shuttle. Students, along with their schools, proposed research projects that met NASA-imposed standards, such as requiring that the experiment fit in the standard container, which could be no heavier than 91 kg (200 pounds), have scientific intent, and be safe. For biological experiments, only insects that could survive 60 to 90 days were allowed. The payload had to be self-contained, require no more than six crew operations, and be self-powered (not relying on the Orbiter's electricity). The payload bay was in the vacuum and thermal conditions of spaceflight, so meeting these goals was difficult.

DuVal High School (Lanham, Maryland) students look inside a Get Away Special canister to see whether any of the roaches survived spaceflight.



DuVal High School in Lanham, Maryland, however, did experience success with their experiment—Get Away Special 238, which flew on STS-95 (1998). The National Capital Section of the American Institute of Aeronautics and Astronautics, a professional society, and the school district (through fund-raisers) financed this project.

From day one, the students wished to fly a biological experiment and debated whether to select termites or cockroaches since both could survive in a dark, damp environment. Once a decision was made, DuVal's project became known as the Roach MOTEL—an acronym for Microgravity Opportunity To Enhance Learning. The insects included three adults, three nymphs, and three egg cases sealed in separate compartments of a habitat inside a Get Away Special can that had sufficient life support systems for a journey into space and back—a journey lasting no longer than 6 months. The students expected the roaches to carry out all life functions (including reproduction) and return alive. The project stretched on for more than 7 years while students and teachers entered and left the program. The two factors that finally brought the project to completion were a team of administrators and teachers that was

determined to see it through and NASA's relaxation of the dry nitrogen/dry air purge of the canister. The ability to seal the Get Away Special can with ambient air was the key to success for this experiment. Over the course of 7 years, 75 adults from 16 companies and organizations assisted with the project. Seventy-seven students were directly involved with engineering solutions to the many problems, while hundreds of other students were exposed to the project. Two roaches survived, and the egg cases never hatched.

Nelson Columbano, one of the students, described the experience as follows:

"I was involved with the Get Away Specials Program at DuVal High School in Lanham, Maryland, in 1996/97. Our project involved designing a habitat for insects (roaches) to survive in orbit for several days. I can't say the actual experiment is something I'm particularly proud of, but the indirect experiences and side projects associated with planning, designing, and building such a complex habitat were easily the most enriching part of my high school experience. The Get Away Specials Program introduced me to many aerospace industry consultants who volunteered to work with the class. It also presented me with real-world challenges like calling vendors for quotes, interviewing experts in person and over the phone, evaluating mechanical and electrical devices for the project and other activities that gave me a glimpse of what it's like to interface with industry professionals. At the end of the school year, some of the consultants came back to interview students for summer internships. I was lucky to receive an offer with Computer



Sciences Corporation, 11 years later becoming the proud IT Project Manager. I often think about how different my career path may have been without the Get Away Specials Program and all of the doors it opened for me.”

The Get Away Specials Program was successful for both high school and university students. Over the years, it changed to the Space Experiment Module Program, which simplified the process for students and teachers.

Space Experiment Modules

To reduce costs to get more students involved, NASA developed the Space Experiment Module Program since much of the engineering to power and control experiments was done for the students. Space Experiment Module experiments, packaged 10 modules to a payload canister, varied from active (requiring power) to passive (no power). Since no cost was involved, students in kindergarten as well as college students proposed projects. During the mid 1990s, 50 teachers from the northeastern United States, participating in the NASA Educational Workshops at Goddard Space Flight Center and Wallops Flight Facility, designed Space Experiment Modules with activities for their students. During this 2-week workshop, teachers learned about the engineering design process and designed module hardware, completed the activities with their students, and submitted their experiment for consideration. One of the Get Away Special cans on STS-88 (1998) contained a number of Space Experiment Module experiments from NASA Educational Workshops participants. Students and teachers

attended integration and de-integration activities as well as the launch.

Martin Crapnell, a retired technology education teacher who attended one of the NASA Educational Workshop sessions, explained.

“Experiencing the tours, briefings, and launch were once-in-a-lifetime experiences. I tried to convey that excitement to my students. The Space Experiment Modules and NASA Educational Workshops experience allowed me to share many things with my students, such as the physics of the thrust at launch and the ‘twang’ of the shuttle, long-term space travel and the need for food (Space Experiment Modules/Mars Lunchbox), spin-offs that became life-saving diagnostics and treatments (especially mine), job opportunities, and manufacturing and equipment that was similar to our Technology Lab.

“Even though delays in receiving all of the Space Experiment Modules materials affected the successful completion we desired, I believe I was able to share the experience and create more excitement and understanding among the students as a result of the attempt. The Space Experiment Modules and NASA Educational Workshops experiences allowed relevant transfer to lab and life experiences.”

A Nutty Experiment of Interest

One of the many experiments conducted by students during the Space Shuttle Program was to determine the effects of microgravity and temperature extremes on various brands of peanut butter. Students microscopically examined the peanut butters, measured their viscosity,

and conducted qualitative visual, spreadability, and aroma tests on the samples before and after flight. The students from Tuttle Middle School, South Burlington, Vermont, and The Gilbert School, Winsted, Connecticut, called this research “a nutty idea.”

Students Go On to Careers in Engineering

John Vellinger, executive vice president and chief operating officer of Techshot, Inc. (Greenville, Indiana), is an example of how one participating student secured a career in engineering.

As an eighth-grade student in Lafayette, Indiana, Vellinger had an idea for a science project—to send chicken eggs into space to study the effects of microgravity on embryo development. Vellinger entered his project in a science competition called the Shuttle Student Involvement Program, sponsored by NASA and the National Science Teachers Association.

In 1985, after Vellinger’s freshman year at Purdue University, NASA paired him with Techshot, Inc. co-founder Mark Deuser who was working as an engineer at Kentucky Fried Chicken (KFC). Through a grant from KFC, Deuser and Vellinger set out to develop a flight-ready egg incubator.

By early 1986, they completed “Chix in Space” hardware was launched aboard Space Shuttle Challenger on its ill-fated STS-51L (1986) mission. Regrouping after the tragic loss of the shuttle, its crew, and the Chix in Space incubator, Deuser and Vellinger continued to develop the payload for a subsequent flight. Together, the pair designed, fabricated,



and integrated the flight hardware, coordinated the project with NASA, and assisted the scientific team.

More than 3 years after the Challenger accident, Chix in Space successfully reached orbit aboard Space Shuttle Discovery on mission STS-29 (1989). The results of the experiment were so significant that the project received worldwide interest from gravitational and space biologists, and it established a strong reputation for Techshot, Inc. as an innovative developer of new technologies.

Spaceflight Science and the Classroom

Can students learn from Space Shuttle science? You bet they can. To prove this point, life sciences researchers took their space research to the classroom.

Bone Experiment

STS-58 (1993), a mission dedicated to life science research, had an experiment to evaluate the role of microgravity on calcium-essential element for health. With the assistance of Lead Scientist Dr. Emily Holton, three sixth-grade classes from the San Francisco Bay Area in California conducted parallel experiments to Holton's spaceflight experiment. Research staff members traveled to the schools 10 days prior to the launch date. They discussed the process of developing the experiment and assembling the flight hardware and reviewed what was needed to include the experiment on the shuttle flight. The students conducted experiments on cucumber, lettuce, and soybean plants



Japanese Astronaut Mamoru Mohri talks to Japanese students from the aft flight deck of the Space Shuttle Endeavour during the STS-47 (1992) Spacelab-J mission.

using hydroponics—the growing of plants in nutrient solutions with or without an inert medium to provide mechanical support. Half the plants were fed a nutritionally complete food solution while the other half was fed a solution deficient in calcium. During the 2 weeks of the mission, students measured each plant's height and growth pattern and then recorded the data. Several of the students traveled to Edwards Air Force Base, California, to witness the landing of STS-58. The students analyzed their data and recorded their conclusions. The classes then visited NASA Ames Research Center, where they toured the life science labs and participated in a debriefing of their experiment with researchers and Astronaut Rhea Seddon.

Fruit Flies—How Does Their Immune System Change in Space?

Fruit flies have long been used for research by scientists worldwide because their genome has been completely mapped, their short life cycle enables multiple generations to be studied in a short amount of time, and they have many analogous processes to humans. The fruit fly experiment flew on STS-121 (2006). Its goal was to characterize the effects of space travel (including weightlessness and radiation exposure) on fruit flies' immune systems.

Middle school students (grades 5-8) were directed to a Web site to follow this experiment. The Web site provided information about current NASA space biology research, the scientific method, fruit flies, and the immune system.



Using documentation on the special site, teachers and their students conducted hands-on activities relating to this experiment. Students communicated with expert fly researchers, made predictions about the results, and asked questions of the scientists.

Frogs in Space—How Does the Tadpole Change?

In the United States and Japan's quest to learn how life responds to the rigors of the space environment, NASA launched STS-47 (1992)—a Japanese-sponsored life science mission. The question to be answered by this mission was: How would space affect the African clawed frog's life cycle? The life cycle of this particular frog fit nicely into this time period. Fertilized eggs were packaged in small grids, each housed in specially designed plastic cases. Some of these samples were allowed to experience microgravity during the mission, while others were placed in small centrifuges and kept at various simulated gravities between microgravity and Earth environment. The education portion of the experiment allowed student groups and teachers to learn about the frog embryology experiment by studying the adaptive development of frogs to the microgravity environment. NASA produced an education package and educational CD-ROM from this experiment.

Teachers Learn About Human Spaceflight

"Reach for your dreams, the sky is no limit," exclaimed Educator Astronaut Barbara Morgan while encouraging teachers to facilitate their students' discovery, learning, and sharing about human spaceflight.

The excitement of spectacular shuttle launches and on-orbit science enriched students' learning. For 30 years, the Space Shuttle Program provided teachers around the nation an unparalleled opportunity to participate in professional development workshops—promoting students to get hooked on science, technology, engineering, and mathematics careers. Historically, NASA has focused on teachers because of their profound impact on students. The main objective of NASA teacher programs was professional development while providing numerous classroom and curriculum resources.

Exciting educator workshops with themes such as "Blastoff into Learning"

or "Ready, Set, and Launch" focused on the Space Shuttle as a classroom in space. Teachers responded enthusiastically to these initiatives.

Damien Simmons, an advanced placement physics teacher at an Illinois high school, said it best after attending a Network of Educator Astronaut Teachers workshop at the NASA Glenn Research Center in Cleveland, Ohio. "I'm taking home lessons and examples that you can't find in textbooks. When my students see the real-world applications of physics, I hope it will lead them to pursue careers in engineering."

Melanie Brink, another teacher honored by the Challenger Center, said, "Embracing the fundamentals of science has always been at the core of my curriculum. Preparing students to be successful young adults in the age of technology, math, and science is an exciting challenge."

NASA continues to provide teachers opportunities to use spaceflight in their classrooms to promote education.



City of Bellflower, California, luncheon "Reaching for the Stars/Growing Together" honored teacher Pam Leestma's second- and third-grade students for their spaceflight learning activities.

Back row (left to right): Kaylin Townsend, Jerron Raye, Brendan Mire, Payton Kooi, and Rylee Winters. Front row: Julianne Bassett and teacher Pam Leestma.



Barbara Morgan

*Educator astronaut on STS-118 (2007).
Idaho teacher.*

"Inspiring and educating future scientists and engineers are major accomplishments of the Space Shuttle Program. Much of this began with the Teacher in Space Program, despite the tragic 1986 loss of Space Shuttle Challenger and her crew.

"Before Challenger, American teachers were stinging from a report, titled 'A Nation at Risk,' that condemned the American education system and appeared to tar all teachers with the same broad brush. Even the noble call to teaching was dismissed, by many, with the saying, 'Those that can, do. Those who can't, teach.'

"But NASA was the first federal agency to start to turn that around, by making a school teacher the first 'citizen' spaceflight participant. NASA selected a stellar representative in New Hampshire social studies teacher Christa McAuliffe, who showed what great teachers all over the country do. I was fortunate to train as Christa's backup. Barely a day went by without NASA employees coming up to us to tell us about those teachers who had made a difference for them. We felt that Teacher in Space was more than just a national recognition of good teaching; it was also a display of gratitude by hundreds of NASA employees.

"Thousands of teachers gathered their students to watch Christa launch on board Challenger. The tragic accident shook all of us to the core. But for me, the pain was partly salved by what I saw in the reactions of many to the tragedy. Instead of defeatism and gloom, I heard many people say that they'd fly on the next Space Shuttle 'in a heartbeat.' Others told me how Challenger had inspired them to take bold risks in their own lives—to go back to college or to go into teaching. Also, 112 Teacher in Space finalists made lasting contributions to aerospace education in this country. And the families of the Challenger crew created the superlative Challenger Center for Space Science Education.

"After Challenger, NASA's education program grew in many ways, including establishing the Teaching From Space office within the Astronaut Office, and producing many astronaut-



taught lessons from orbit to school children around the world. I returned to teaching in Idaho, and continued working with NASA, half-time, until I became an astronaut candidate in 1998. I am proud that NASA later selected three more teachers to be educator astronauts. It marked the first time since the scientist astronauts were selected for Apollo that NASA had made a major change in its astronaut selection criteria.

"So, certainly, the Space Shuttle Program has made a major impact on American education and on the way teachers are seen by the public. And this brings me back to that old comment of 'Those who can't, teach.' It reminds me of how, to pay tribute to those who went before, engineers and scientists are fond of quoting Sir Isaac Newton. He said, 'I stand on the shoulders of giants.' We teachers have a similar sense of tradition. We think of teachers who teach future teachers, who then teach their students, who go on to change the world. For example, Socrates taught Plato, who taught Aristotle, who taught Alexander the Great. So I'd like to end this little letter with a quote that far predates 'Those who can't, teach.' Two millennia ago, in about 350 BC, Aristotle wrote, 'Those who know, do. Those who understand, teach.' Aristotle understood.

"I want to thank the Space Shuttle Program for helping teachers teach. Explore, discover, learn, and share. It is what NASA and teachers do."



College Education

Undergraduate Engineering Education

A legacy of building the shuttle is strengthening the teaching of systems engineering to undergraduate students, especially in design courses. The shuttle could not have been designed without using specific principles. Understanding the principles of how systems engineering was used on the shuttle and then applying those principles to many other design projects greatly advanced engineering education.

Engineering science in all fields of engineering was advanced in designing the shuttle. In the fields of avionics, flight control, aerodynamics, structural analysis, materials, thermal control, and environmental control, many advances had to be made by engineers working on the Space Shuttle—advances that, in turn, were used in teaching engineering sciences and systems engineering in universities.

The basic philosophy underlying the teaching approach is that the design must be a system approach, and the entire project must be considered as a whole rather than the collection of components and subsystems. Furthermore, the life-cycle orientation addresses all phases of the system, encouraging innovative thinking from the beginning.

The use of large, complicated design projects rather than smaller, more easily completed ones forces students to think of the entire system and use advanced engineering science techniques. This was based on the fact that the shuttle itself had to use

advanced techniques during the 1970s. The emphasis on hierarchical levels provides an appreciation for the relationship among the various

functions of a system, numerous interface and integrating problems, and how the design options are essentially countless when one

Katie Gilbert

Inspired by NASA to become an aerospace engineer.



"In the school year of 2000, NASA released an educational project for elementary-aged students. Of course, this project reached the ears of my fun-seeking fourth-grade science teacher, Mrs. Maloney. For extra credit, we were to group ourselves up and answer the critical question: What product could be sent up to space on the shuttle to make our astronauts' lives easier?"

"For weeks, our fourth-grade selves spent hours of time creating an experiment that would answer this question. My group tested cough drops; would they still have the same effectiveness after being in zero gravity for extended periods of time? We sent it in, and months later we received a letter. Four of our school's projects were to be sent up on the Space Shuttle Endeavour. Our projects were going to space!"

"When the time finally came, we all flew down to Florida to watch Endeavour blast off with our experiments on board. This all gave me the opportunity to visit the Kennedy Space Center, see a real Space Shuttle, and talk to actual astronauts. The entire experience was one of the most memorable of my life. With all of the excitement and fascination of the world outside of ours, I knew right then that I wanted to be an astronaut and I made it my life goal to follow my cough drops into space."

"As it turns out, cough drops are not at all affected by zero gravity or extreme temperatures. The experiment itself didn't bring back alien life forms or magically transform our everyday home supplies into toxic space objects, but it wasn't a complete waste. The simple experiment opened my eyes to the outside world and the possibilities that exist within it. It captivated my interest and held it for over 8 years, and the life goals I made way back then were the leading factor in choosing Purdue University to study Aerospace Engineering."



considers all the alternatives for satisfying various functions and combinations of functions.

Also, learning to design a very complex system provides the skills to transfer this understanding to the design of any system, whereas designing a small project does not easily transfer to large systems. In addition, this approach provides traceability of the final system design as well as the individual components and subsystems back to the top-level need, and lowers the probability of overlooking an important element or elements of the design.

For designing systems engineering educational courses, general topics are addressed: the general systematic top-down design process; analysis for design; and systems engineering project management. Specific topics are: establishment and analysis of the top-level need with attention to customer desires; functional decomposition; development of a hierarchical arranged function structure; determination of functional and performance requirements; identification of interfaces and design parameters; development of conceptual designs using brainstorming and parameter analysis; selection of criteria for the evaluation of designs; trade studies and down-selection of best concept; parametric analysis; and preliminary and detailed designs. Application of engineering analysis includes the depth and detail required at various phases during the design process. Systems engineering management procedures—such as failure modes and effects analysis, interface control documents, work breakdown structures, safety and

risk analysis, cost analysis, and total quality management—are discussed and illustrated with reference to student projects.

In summary, due to NASA's efforts in systems engineering, these principles were transferred to undergraduate engineering courses.

Graduate Student Science Education

The Space Shuttle's impact on science and engineering is well documented. For scientists, the shuttle enabled the microgravity environment to be used as a tool to study fundamental processes and phenomena ranging from combustion science to biotechnology. The impact of the microgravity life and physical science research programs on graduate education should not be overlooked.

Many graduate students were involved in the thousands of experiments conducted in space and on the ground. A comparable number of undergraduates were exposed to the program. Perusal of task books for microgravity and life science programs reveals that, between 1995 and 2003, flight and microgravity research in the life and physical sciences involved an average of 744 graduate students per year. Thus, the shuttle provided thousands of young scientists with the opportunity to contribute to the design and implementation of experiments in the unique laboratory environment provided by a spacecraft in low-Earth orbit. Such experiments required not only an appreciation of a specific scientific discipline, but also an appreciation of the nature of the

microgravity and how weightlessness influences phenomena or processes under investigation.

In addition to mainstream investigations, shuttle flight opportunities such as the self-contained payloads program—Get Away Specials—benefited students and proved to be an excellent mechanism for engineering colleges and private corporations to join together in programs oriented toward the development of spaceflight hardware.

All shuttle science programs significantly enhanced graduate education in the physical and life sciences and trained students to work in interdisciplinary teams, thus contributing to US leadership in space science, space engineering, and space health-related disciplines.

